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A review of demand-side management policy in the UK

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ABSTRACT

Demand-side management (DSM) refers to actions undertaken on the demand side of energy metres. A broad definition of DSM is proposed to include current policy objectives for emissions reduction, energy security and affordability, and encompasses energy efficiency, demand response, and on-site back-up generation and storage. The paper reviews the concept of DSM, outlines the historical impacts of DSM globally since the energy crises of the 1970s, analyses UK DSM policy, and examines the influence of EU Directives on UK DSM policy, as the country is currently deciding on how to include the demand-side in its *Electricity Market Reform* proposals and wider energy policy. Much of the focus of previous research has been on DSM technological trials and modelling studies rather than DSM policy and the paper contributes to filling this gap. Policy recommendations for the UK context are discussed, and it is clear that the success of DSM policies is determined primarily by regulatory support and utility financial incentives. It is important that policy clarity is provided and that current and new policies do not overlap.

Contents

1. Policy objectives

Environmental and energy security issues are increasingly moving to the forefront of the political agenda, as governments seek to develop energy policies that meet objectives for carbon emissions reduction, energy security and affordability.

Energy production and consumption are widely regarded as key contributors to anthropogenic climate change. The International Energy Agency (IEA) estimates that ~70% of world energy production is produced through the burning of fossil fuels, primarily coal (42%) and gas (21%), and energy accounts for 40% of anthropogenic carbon dioxide and other greenhouse gas emissions (CO_{2e}). The demand for energy is growing as national populations expand, particularly in emerging economies, and the growth of gadgets and technology in society continues [1].

Balancing energy supply and demand has been a complex challenge in many countries, with reserve capacity margins of ~20% commonly used to deal with peak demands [2], such as when people turn their kettles on after a popular television programme or on a particularly cold winter night [3]. However, with flexible generation plants powered by fossil fuels, matching supply with demand has been effectively administrated in most

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countries. Traditionally, energy utilities have invested in expanding their capacity base to deal with long-term increases in energy demand [4]. With growing awareness regarding the contribution of fossil fuel generation to climate change, energy utilities are coming under political pressure to diversify their fuel mixes to lower carbon alternatives.

A growing number of countries are also becoming more dependent on fuel imports, such as coal, oil and gas, than domestic supplies. In some cases the imports are sourced mainly from specific regions, such as Europe's dependence on Russian gas and Middle Eastern oil [5]. Dominance of fossil fuel energy resources has increased the geopolitical power of the exporting regions as energy moves up the political agenda [5]. Hence, growing energy demands, the political drive to move to lower carbon energy sources and the growing dependence on fuel imports, have resulted in policy debates regarding the security of energy supply. Furthermore, these factors often contribute to increasing energy prices, which counters a fundamental principle of energy policy – affordability.

2. Proposed solutions

Proposed solutions to the energy security challenge include building new capacity, increasing interconnections with other countries, developing energy storage technologies, and demand-side management [6]. All of these options will be important in the future [7]. In regions like Europe, political pressure is mounting on energy utilities to invest in new capacity that is low(er) carbon. Nuclear power has been pursued in a number of countries, though following the Fukushima-Daiichi disaster in Japan in March 2011 many governments have started to question their nuclear policies [8]. Furthermore, nuclear power has been used as base load in a number of energy systems, due to its inflexible operational nature for technical and economic reasons [9]. Wind power, one of the more developed and favoured low carbon alternatives, suffers from variable power production due to wind speed variations, causing new challenges in matching supply and demand [4]. Other technologies are currently underdeveloped and at the demonstration stages, such as wave and tidal power, and carbon capture and storage (CCS). Many of these options are currently expensive as they are in the early stages of commercial maturity.

Building new capacity as back-up power is costly as the power plants are only used infrequently during peak times. Alternatively, there is a growing interest in the role that interconnection can play, particularly in the common European market. Interconnection refers to the cross-border transmission of electricity along high voltage power lines between countries, though this requires the right infrastructure and regulatory transaction processes to be in place ([10], p. 5). For example, the UK currently has interconnections with France, Ireland and the Netherlands with a combined capacity of ~3.5 gigawatts (GW), and is considering plans to build interconnectors with Norway, Belgium and Iceland [165]. Nevertheless, unless interconnections are more far reaching geographically, they may make little difference to countries experiencing the same weather patterns if wind is pursued as a major power source [11].

Energy storage is likely to play an important role in the future but storage technologies are currently at the research and testing stages. Pumped hydro is one of the only commercially developed and widely used technologies, but it has geographical limitations in the extent of its development [12]. Furthermore, the geographically distributed nature of variable renewable sources may prevent certain energy storage systems from being practicably installed [13]. Other storage options include flywheels, compressed air energy storage, electric vehicle batteries, and large thermal storage tanks [14].

Many of the proposed solutions to meeting the policy objectives come from the traditional approach of matching supply with demand. Demand-side management (DSM) aims to reverse this thinking by looking at how to match demand with the available supply. DSM complements the other solutions and actively engages consumers in a market that has historically been 'invisible' to them ([15], p. 3). Overcoming climate change and energy security issues involves significant changes in behaviour in addition to cleaner technologies [16].

This paper reviews the concept of DSM (Section 3), outlines the historical impacts of DSM globally since the energy crises of the 1970s (Section 4), analyses UK DSM policy (Section 5), and examines the influence of EU Directives on UK DSM policy (Section 6). The UK is currently deciding on how to include the demand-side in its *Electricity Market Reform* proposals and wider energy policy, and the final section of the paper provides policy recommendations to feed into this process (Section 7).

Much of the focus of previous research has been on trials of DSM technologies and studies that model the potential of DSM to meet certain objectives. However, much less attention has been given to reviewing DSM policies, which have been implemented by governments over national or regional scales. The paper aims to contribute to filling this gap. Work-in-progress is undertaking a Systematic Review of international experiences with DSM policies to determine how and why they work or fail and how transferable successful policies are between countries. This paper presents the results of an extensive two-year long review of over 200 publications and focuses primarily on an analysis of the UK context.

3. Demand-side management: contested definitions

The term 'demand-side management' (DSM) was first coined by Clark Gellings (Electric Power Research Institute, USA) in 1984 [17], which was historically known as load management:

> "DSM activities are those which involve actions on the demand (i.e. customer) side of the electric metre, either directly or indirectly stimulated by the utility. These activities include those commonly called load management, strategic conservation, electrification, strategic growth or deliberately increased market share [18].

In the past, DSM programmes have often concentrated more on the management of electricity demand rather than on (non-electric-based) heating and transport, though DSM can encompass non-electric energy measures, such as co-generation (the production of both heat and power), district heating/cooling and heat micro-generation technologies (such as solar thermal panels). The review found that the definitions of DSM vary in what they include or exclude. Some publications include the management of electricity demand but not other forms of energy demand (e.g. [19]), others use the definition synonymously with that of the smart(er) grid (e.g. [20]), some refer to DSM as measures that reduce energy demand at peak times (e.g. [21,22]), while others use a similar definition but also include the response of consumers to price changes and the shifting of load to off-peak times (e.g. [23]). Micro-generation is included in some definitions (e.g. [24]), and some include or exclude energy efficiency measures (e.g. [25]).

DSM aims to better match demand with the available supply as a cheaper alternative for energy utilities than investing in new generation capacity. Gellings and Chamberlin [18] argue that DSM tries to encourage utilities to put demand-side measures on an equal level with supply-side options (pp. 3–4). It also aims to actively engage consumers in the management of their energy use

and how they can save money through making their consumption more 'visible' and important to them ([26], p. 13). If overall energy demand is reduced (rather than load shifting), DSM can reduce CO_{2e} emissions. Gellings and Chamberlin [18]'s definition quoted above is useful but it arguably does not directly include current policy priorities in many countries to reduce overall energy consumption as part of the path to reduce CO_{2e} emissions. Eissa [24] states that the overall goal of DSM should now be to reduce overall energy demand and shift patterns of consumption to help smooth demand. Such a definition would then exclude some traditional aspects of DSM, such as strategic load growth, where utilities deliberately increase loads in times of excess capacity [18], which could become more common under conditions of surplus wind power and limited storage capabilities.

Eissa's [24] definition is broad and covers a full spectrum of actions and specific technologies. The definition is more recent and covers a wider set of technologies: load management, energy efficiency (using less energy to provide the same services), demand response (the response of customers to incentive payments or price changes – see Albadi and El-Saadany [27]), energy storage, and micro-generation (the small scale production of energy, often < 50 kW). This research proposes the following holistic definition of DSM to extend this by collating and updating the definitions from the reviewed publications to better suit current policy objectives for emissions reduction, energy security and affordability:

> "Demand-side management (DSM) refers to technologies, actions and programmes on the demand-side of energy metres that seek to manage or decrease energy consumption, in order to reduce total energy system expenditures or contribute to the achievement of policy objectives such as emissions reduction or balancing supply and demand."

Figure one categorises DSM based on the proposed definition and the findings from the review. The diagram is split into three parts: DSM categories, implementers and policies.

Gellings and Chamberlin [18] generally refer to energy efficiency and energy conservation synonymously. However, energy efficiency is the ratio of the useful output of a process to the energy input into a process [28]. Thus, improving energy efficiency may reduce the amount of energy needed to perform the same function, but there is no guarantee that energy use will reduce; it may stay at the same level, or even increase, due to the capital from energy savings being used to increase output without increasing overall expenditures. This has been termed the 'rebound effect' ([29], pp. v–vi) and may be split into direct rebound, where consumption is increased in the same activity, and indirect rebound, where consumption is increased in another activity ([29], pp. v–vi). In contrast, energy conservation aims to reduce the overall energy demand throughout the year [20].

Gellings and Chamberlin's [18] definition concentrates mainly on load shapes, which are often utility-controlled or utility-stimulated. Hence, the key difference between their definition and the proposed definition is that the former is more utility-focussed and the latter is more focussed on government policy objectives. As discussed previously, the former definition includes strategic load growth, which may be a result of increased market share of loads that are served by competing fuels as well as economic development in the service area ([18], p. 239; [17]). Although the proposed definition broadly agrees with the categorisation of DSM types in Gellings [17] (peak clipping, valley filling, load shifting, strategic conservation, strategic load growth, and flexible load shape), it focuses on actions, measures and programmes that reduce overall energy demand or time-shift loads rather than increase them, thus reflecting current policy objectives.

The three broad categories shown in Fig. 1 are the main types of DSM referred to in the literature. Energy efficiency generally aims to reduce overall energy demand, whereas demand response concentrates more on shifting energy consumption during peak times to help balance supply and demand. In the UK, on-site backup generation and storage has historically been used for smoothing the load curve to reduce peaks, such as through diesel generators in industry and hot water storage tanks in houses.

Fig. 1 also conveys the main implementers of DSM programmes. However, DSM policy, as designed by governments, is most commonly implemented through utilities (and to a lesser extent, Distribution Network Operators (DNOs)). Although beyond the scope of this paper, it is clear from the review that utility financial incentives and regulatory support are key determinants of the success of a DSM policy.

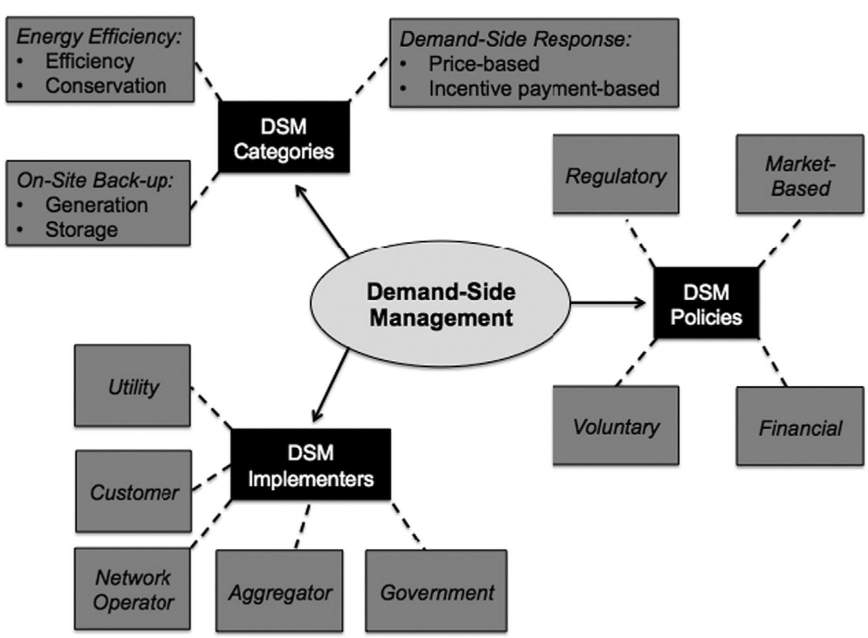

Fig. 1. Defining demand-side management (DSM).

The third branch of Fig. 1 breaks down DSM policy into four categories: regulatory, market-based, voluntary, and financial. The list below provides frequently discussed and implemented policies:

Regulatory:

- product (appliance, equipment, building) standards
- product (appliance, equipment, building) labelling
- utility obligations

Market-based:

- certificate trading schemes
- market transformations
- demand response tariffs

Financial:

- loans and subsidies
- system benefits charges
- research and development programmes (funding)

Voluntary:

- information campaigns
- voluntary programmes

Work-in-progress is analysing the success of these policies in different countries and their transferability between countries, and the results are forthcoming.

4. Review of global DSM policy

Although DSM is receiving growing research and political attention as a result of the low carbon agenda, energy security issues and the development of the smart(er) grid, harnessing demand-side flexibility is not new ([30], p. 11). The concept of DSM in policy can be traced back to the USA's *National Energy Conservation Policy Act* and *Public Utility Regulatory Policy Act* (PURPA), which were introduced as part of the *National Energy Act 1978* (McNerney, 1998, p. 27 [40]). This was the first instance of DSM being legislated nationally as a solution to the energy security issues of the 1970s. Nevertheless, the *notion* of DSM has been around for a long time, traditionally referring to a utility's general load management or through the use of hot water tanks and off-peak storage heaters in houses [6]. The latter was particularly the case in New Zealand and Europe in the 1960s and 1970s [17]. However, PURPA was the first instance of DSM in government policy.

The 1970s energy crisis particularly affected the USA and was caused by the Arab Oil Embargo of OAPEC (Organisation of Arab Petroleum Exporting Countries) in 1973–1974 and the Iranian Revolution in 1978–1979 ([31], pp. 14–16). PURPA introduced *Integrated Resource Planning* (IRP), which involves energy utilities evaluating options for meeting future electricity demands and providing energy services at minimal societal costs to customers ([32], p. 43). Options include DSM (particularly energy efficiency and demand response) in addition to traditional supply-side options and the utilities choose the least-cost combination of resources ([32,33], p. 43). DSM programmes grew in the USA in the 1980s and 1990s and by 1995, 600 energy utilities had conducted 2300 programmes involving 20 million participants ([32,34], p. 54). Notably, between 1989 and 1995, 260,000 gigawatt-hours (GWh) were saved from a cumulative spending of USD 14 billion ([32,35], p. 54). Post-1995 DSM programmes declined in the USA as energy security issues became less prominent and Gellings [36] argued that their future was in doubt.

DSM did not achieve the same interest or success in Europe as it did in the USA, and this is arguably due to a lack of a European equivalent to PURPA, which also pre-dated the formation of the European Union (EU) in 1993 (as a result of the *Maastricht Treaty* in 1992). Gellings [36] speculated that Europe had a similar degree of development as the USA in the 1980s and 1990s. Although energy conservation and energy efficiency measures were given more attention in political circles in the 1980s following the energy crises, market liberalisation and deregulation in the 1990s removed many energy utilities' interest in DSM [210]. Market liberalisation is defined as the transformation from monopolistic publicly owned production and distribution to privatised markets, with various competing firms [37]. The policy led to a market based on the quantity of electricity sold and thus, many energy utilities perceived energy conservation as at odds to the profitability of their businesses ([32], p. 56).

Despite this, there has been renewed interest in DSM in the 2000s and 2010s across the world as a result of climate change and energy security issues coming to the forefront of the political agenda. This is in contrast to the predictions of Gellings [36], who argued that the development of DSM in developed countries would continue to decline. Recent figures show that the combined annual utility expenditure across 18 states in the USA is $>$USD 900 million with annual incremental savings of ~2.8 million megawatt-hours (MWh) ([38]). The International Energy Agency's DSM Programme (IEA DSM Programme) has supported the advancement of DSM research globally since 1993 through a number of tasks and it aims to be the main source of DSM information and tools for governments and other institutions. Its growing database of country case studies from around the world (IEA DSM, 2004) highlights the increasing number of governments engaging with DSM as an alternative to supply-side solutions.

Fig. 2 summarises the countries that were most frequently discussed in the publications included in the review.

An interesting temporal and spatial observation is that North American countries dominated the literature in the 1970s–1990s, European countries were prominent in the literature in the 1990s–2010s, and more recently Asian countries, notably China, South Korea, India and Thailand, are beginning to receive greater attention (e.g. [159,219,206]). Fig. 2 only covers countries that were discussed in relation to DSM *policy* implementation rather than non-government-stimulated programmes or trials.

5. Review of UK DSM policy

5.1. DSM's role in the Balancing Mechanism

The UK has a Balancing Mechanism to balance supply and demand during peak times. This has been dominated by back-up generation, which is often inefficient, high-carbon and expensive to operate, as it is only used for a few hours per year [39]. Storage, interconnection and DSM are alternatives, though the inclusion of DSM in the Balancing Mechanism has been limited to date. National Grid, the system operator, had total requirements of 4.7 GW in 2011–2012 and Ward et al. [53] estimate that ~1.5 GW of DSM capacity was contracted, the majority of which was provided through on-site back-up generation with demand response contributing only ~200 MW. Ancillary services can be provided through the Short Term Operating Reserve (STOR), Fast Reserve, Firm Frequency Response, and Frequency Control. The ~1.5 GW of existing DSM capacity contributes mainly to STOR and

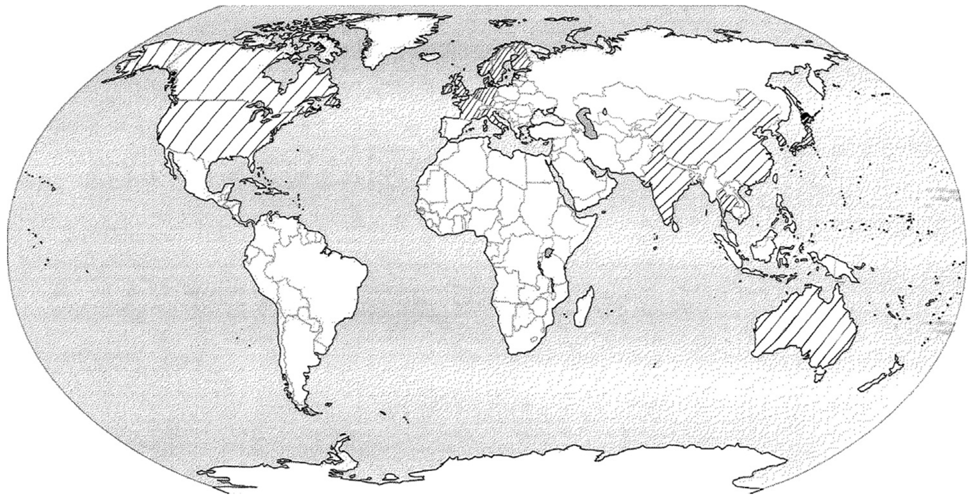

Fig. 2. Countries that have implemented DSM policies.

Table 1
Requirements for participation in the UK's Balancing Mechanism (collated from: National Grid, [170]; [42]; National Grid [43]).

Balancing Service	Short Term Operating Reserve	Fast Reserve	Frequency Response	Frequency Control by DSM
Minimum participation	3 MW (can be aggregated)	50 MW	10 MW	3 MW (can be aggregated)
Delivery time	240 min	2 min	Automatic	2 s
Sustained response	2 h	15 min (at 25 MW/min)	–	30 min (available 24 h/day)
Economic revenue	£25–35/kW/year	£40–50/kW/year	£50–55/kW/year	–

is provided through interruptible/curtailment contracts with large industries, which are paid to reduce energy consumption during peak times [41,42]. Table 1 summarises the requirements for participation in the UK's Balancing Mechanism.

Frequency response is necessary when demand exceeds the frequency of electricity supply (50 Hz in the UK), causing a drop in frequency as generators (slightly) slowdown [42]. This can occur as a result of inaccurate forecasts or a generation disruption event (ibid.). Firm Frequency Response is an automatic change in demand (or power output) in response to frequency changes and DSM's contribution (such as through load management and the interruption of smelting activities) was ~8% of the maximum requirement of ~1200 MW in 2012 [165].

The STOR average contracted utilisation payment from National Grid was £225/MWh in 2011 and for Firm Reserve it was £22,000/MW [42]. The economic revenue from 3 MW of demand-side participation in STOR would be £66,000/year (availability revenue) and £35,000–£55,000/year (utilisation revenue based on 50–80 one hour utilisation periods per year) (ibid.). Thus, there is a role for utilities or separate DSM companies to aggregate reductions from different smaller loads to meet the requirements for entering the Balancing Mechanism. Despite this, although supply- and demand-side participation are treated equally, utilities often favour more traditional supply-side options due to the increased certainty of response (unless the demand-side response is automatically controlled and not overridden by the consumer). Thus, there is a role for policy support to increase the participation of the demand-side as an economically efficient means of reducing total energy system expenditures.

In 2010 the total energy consumption of the UK non-domestic sectors was ~40.6 GW [54] and in 2012 it was estimated that a potential reduction of ~1.2–4.4 GW was achievable under existing and proposed demand response policy measures in the non-domestic sectors [42]. Hot water has a high flexibility of around 50%, and lighting (through dimming and turning off non-essential lights), air conditioning units and other end uses have flexibilities of ~20% (ibid.). Other potential end uses that can be voluntarily or automatically adjusted during peak periods are heating, catering, computing and refrigeration, with the greatest (non-industrial) demand response potential in the UK being in the retail (~0.7 GW), education (~0.3 GW) and large commercial (~0.3 GW) sectors (ibid.). In the residential and small commercial sectors, UK Department of Trade and Industry (DTI) [41] estimated that ~1 GW of DSM capacity is possible, though details on the required policy support to achieve this were limited.

5.2. DSM's role in Electricity Market Reform

The UK's is currently consulting on its *Electricity Market Reform* (EMR) policy proposals, which aim to reform the current market to incentivise the development of a secure, low(er) carbon electricity system. The proposals include a feed-in tariff with contracts for difference (fixing and guaranteeing the revenue that low(er) carbon generators receive), an Emissions Performance Standard to prevent new coal plants being built (without Carbon Capture and Storage), a Carbon Floor Price to further incentivise the building of low(er) carbon power stations, and a Capacity Market to ensure energy security during peak times. However, the current complexity of contracts in the Balancing Mechanism and the uncertainty regarding how customers could participate in the Capacity Market need to be addressed. Some utilities are beginning to engage with DSM by developing business models that place them as the aggregator, where they organise the contracts and bidding strategies for their participants, such as EDF Energy's ‘Smart Response’ programme that was set up in 2011 for business customers.

The passage of the UK's *Energy Bill* through Parliament during 2013 was criticised for not adequately including the role of the demand-side in the plans for the future electricity system. The government subsequently released an *Electricity Demand Reduction*

consultation, which proposed three main market-wide incentives: a premium payment for electricity efficiency, an energy supplier obligation for electricity efficiency in the non-domestic sector, and payments for participating in the Capacity Market. Each DSM policy will be discussed in turn.

The premium payment would provide participants with a payment in addition to the (potential) savings that result from reduced consumption. An agreed flat fee payment for every unit (kilowatt-hour) of electricity saved would be more effective and administratively easier to implement than a contract-for-difference payment where participants receive payments per kilowatt-hour relative to the strike price (which determines the subsidy a technology receives). Thus, in the latter case, if the electricity price exceeds the strike price participants must pay back part of their savings to equal the strike price [44]. A difficulty with both options is determining what the baseload level of consumption would have been to estimate how much electricity use has reduced.

Since 2002, UK energy efficiency supplier obligations in the residential sector have been effective at increasing the energy efficiency of the current residential building stock and subsequent reductions in carbon emissions. However, the impacts of the obligations have been determined by theoretical conclusions, rather than actual measurements, and despite the administrative difficulties in determining the actual impacts, the success of the policies needs to be determined if a non-domestic supplier obligation is to achieve overall energy reductions. The rebound effects from the obligations are also important to determine (though difficult to measure). The *Energy Efficiency Commitment Phase 1* (EEC1) ran from 2002–2005 with an energy savings target of 62 TWh (terawatt-hours) and achieving 86.8 TWh (Ofgem, 2005 [55]). The *Energy Efficiency Commitment Phase 2* (EEC2) ran from 2005–2008 with a target of 130 TWh and achieving 187 TWh (Ofgem, 2008 [56]). The third phase, called the *Carbon Emissions Reduction Target* (CERT), ran from 2008 to the end of 2012 with a target of 293 $MtCO_2$ (mega-tonnes of carbon dioxide) emissions reduction. CERT ran alongside the *Community Energy Saving Programme* (CESP) for area-based schemes. Although 296.9 $MtCO_2$ emissions reduction was achieved, two of the six suppliers included in the obligations did not meet their targets (Scottish and Southern Energy and British Gas) ([21]).

The most common way for large suppliers to meet these commitments was through installing loft and cavity wall insulation in the premises of their domestic customers. However, it is unclear what measures would be included in a non-domestic *electricity* efficiency supplier obligation, as the majority of non-domestic premises (like households) are fuelled by gas heating in the UK. Despite this, as previously discussed, there is still a large untapped potential in improving the efficiency of lighting and air conditioning, particularly in the commercial sector. Supplier obligations are likely to have a much greater impact than voluntary schemes, such as the *Green Deal*, a policy introduced in October 2012 and re-launched (after initial low uptake rates) in January 2013. The policy utilises a financial mechanism that removes the upfront costs of domestic energy efficiency measures, which are paid back over time through a proportion of the savings made with an interest rate of ~7%. CERT was replaced by the *Energy Company Obligation* (ECO) to run alongside the *Green Deal*. It similarly focuses on the residential sector and runs from 2013 to March 2015, primarily designed to get utilities to install more expensive measures in customers' homes, such as solid wall insulation. The targets are 20.9 $MtCO_2$ savings under a carbon emissions reduction obligation, 6.8 $MtCO_2$ savings under a carbon saving community obligation, and £4.2 billion under a home heating cost reduction obligation [45].

The success of supplier obligations compared to other types of DSM policy is pronounced in the UK. The predecessor to the obligations, the *Energy Efficiency Standards of Performance* (EESOP), which ran in three phases between 1994 and 2002 (EESOP1: 1994–1998, EESOP2: 1998–2000, EESOP3: 2000–2002), achieved substantially less carbon emissions reduction [46]. For example, EEC1 delivered four times as much as carbon as EESOP3 [47]. Mallaburn and Eyre [32] and Rosenow [47] extensively analysed the UK's energy efficiency policies over the last few decades. Preliminary analysis of one of the successors to the obligations, the *Green Deal*, shows that the installation of cavity wall insulation plummeted from ~46,000 installations per month at the end of the CERT period in 2012 to ~1000 installations per month under the Green Deal in 2013 ([97]). Despite this, an issue with all three types of policy is that they have concentrated primarily on the residential sector. As discussed in Section 7, a supplier obligation that targets small-to-medium-sized enterprises and organisations (SMEs) would be a cost-effective means of contributing to meeting policy objectives for carbon emissions reduction, energy security and affordability.

The proposals for including the demand-side in the Capacity Market are needed for the wider development of DSM in the UK electricity system, but it is unlikely that the residential sector will have a significant role in balancing markets due to the complexity for Aggregators to collate a large number of very small loads, the response of which may not be guaranteed due to the much greater number of decision-makers involved. The potentially small amount of income that a resident could earn from participation is unlikely to warrant the effort and time required to reduce consumption when called on to do so and the risk of potential penalties for breaching contracts for not doing so. Incentivising the residential sector to participate in Capacity Markets would be a real administrative and commercial challenge, and other aspects of DSM policy, such as improved product standards, labelling and energy efficiency supplier obligations, may be more suitable approaches. However, at the time of writing the UK Government's response to the *Electricity Demand Reduction* consultation proposes to undertake a pilot scheme to determine how permanent reductions in electricity demand could be delivered via the Capacity Market. Alongside non-financial options, such as an industrial information hub for energy efficiency, this appears to be the Government's preferred approach as opposed to a premium feed-in tariff or a non-domestic supplier obligation.

5.3. Discussion

Current DSM policy in the UK has been criticised by industry due to the complexity and potential overlap of energy and climate policies. This has caused confusion across a number of sectors as to whether or not certain schemes will be scrapped or new policies introduced. Of particular note is the overlap of the *Electricity Demand Reduction* consultation proposals with energy policies, such as the *Energy Efficiency Strategy* (introduced in November 2012 and discusses the role of the Government's new Energy Efficiency Deployment Office), *ECO*, the *Green Deal*, the *Renewable Heat Incentive* (feed-in tariffs for heat micro-generation technologies), *Feed-in Tariffs* (for electricity micro-generation technologies), and climate policies, such as the *Carbon Reduction Commitment Energy Efficiency Scheme* (CRC) (for large non-energy-intensive organisations to report and reduce their emissions), introduced in April 2010, and mandatory carbon reporting for businesses listed on the London Stock Exchange, introduced in April 2013. If DSM is to play an important part of future UK energy policy, clarity, transparency and stability are essential determinants of success.

Despite recent criticism, the UK has been one of the world's leading countries on DSM policy over the last 40 years ([46]), which was recently acknowledged in the ACEEE (American Council

for an Energy Efficient Economy)'s international energy efficiency scorecard (ranked first overall out of 12 leading economies) (ACEEE, 2012 [57]). However, the UK is at risk from undermining its historical success due to the poor design and implementation of some recent innovative policy ideas, and limited understanding of what DSM policies have worked well based on evidence from national and international experiences.

6. EU influence on UK DSM policy

As a member state of the European Union (EU), the UK must comply with EU Directives and regulations. Of recent interest is the *Energy Efficiency Directive* (2012/27/EU), which mandates that all member states must introduce energy efficiency obligation schemes or policy measures; the public sector must play an exemplary role; energy audits must be conducted for all large firms; and consumers must have a right to know how much energy they consume. Furthermore, the *Smart Meter Rollout Directive (2009/72/EC)* mandates that all member states should achieve at least an 80% rollout of smart metering by 2020. Both directives will provide platforms to develop an improved market for DSM. In the latter case, the UK has a target of 100% rollout of smart metres to homes and small businesses between 2015 and 2020 (in 2013 the initial rollout period of 2014–2019 was pushed back by 1 year due to policy design issues).

Smart metres are advanced energy metres that can read real-time energy consumption information, and allow bidirectional communication of data to enable information to be collected regarding any electricity fed back to the grid from customer premises through micro-generation [48]. They are an important enabling technology for allowing a demand response and 'negawatts' market (based on electricity saved – see Lovins [49]) to develop. However, it is imperative that demand response tariffs (such as time-of-use pricing and critical peak pricing – see Albadi and El-Saadany [27]) are introduced alongside the smart meter rollout. Furthermore, it is the In-Home Displays (IHDs) (energy display monitors) that form the consumer interaction rather than the actual smart meters (Darby, 2010 [58]; [50,51]) and the UK government plans to install them alongside the smart meters.

Further development of energy labelling, product standards and certification for appliances and equipment through the EU's *Energy Labelling Framework Directive* (2010/30/EU) and the *Ecodesign Framework Directive* (2005/32/EC), will be key factors in helping to stimulate the market development of energy efficiency. The successful *Energy Star programme* in the USA is being transferred to Europe and should further develop the market. The labelling programme promotes the buying of energy efficient products that have met strict energy efficiency criteria.

The need for DSM in the short term is strengthened by the impact of around a quarter of the UK's current generation capacity coming offline by 2020. This is due to ageing power stations and coal plants closing under the EU's *Large Combustion Plants Directive* (2001/80/EC) on reducing the emissions of certain pollutants (particularly SO_2, NO_x and dust). For example, five of the UK's 14 coal plants of >1000 MW of capacity will come offline by 2016 [199] causing issues for balancing supply and demand.

The EU can have an important influence in aiding the development of DSM policy in the UK. However, there is a need for the UK to go beyond EU Directives to learn from international experiences and understand how and why particular DSM policies are successful and how transferable they are to the UK. This will enhance the development of DSM as a complementary solution to low(er) carbon supply-side solutions, interconnections and large-scale energy storage. Work-in-progress is contributing to filling this knowledge gap and the results are forthcoming.

7. DSM policy recommendations

Section 3 categorised DSM policies into regulatory, market-based, financial, and voluntary. From the review, supplier obligations appear to be one of the most effective regulatory mechanisms for meeting current policy objectives. However, globally, most supplier obligations have mainly concentrated on the residential sector, and there is a potential role for them to be extended to include SMEs, which make up a substantial part of national energy consumption and are often unsupported by policy. This recommendation is further strengthened by other regulatory mechanisms, such as compulsory energy audits and carbon emissions reduction programmes, only targeting the largest energy consumers.

Market-based mechanisms, such as demand response tariffs, have similarly concentrated on the largest consumers, primarily through interruptible/curtailment contracts. However, in France, EDF's Tempo tariff has targeted the residential sector since the 1960s. It is a time-of-use tariff that charges different electricity prices for different days in the year, split into three colour-coded price categories (300 days are blue – low electricity prices, 43 days are white – medium electricity prices, and 22 days are red – high electricity prices) [134]. Nevertheless, few countries have similar tariffs for residential consumers and in France $<20\%$ of residential customers use it ([134]). In the UK, Economy 7 and 10 tariffs have existed for some time (where it is cheaper to use energy at night), but only $\sim$3–3.5 million households are estimated to have Economy 7 m. The smart metre rollout should provide opportunities for a range of demand response tariffs to be introduced. However, this could be limited by the UK Government's recent decision to reduce the number of tariffs to four, which must include a variable rate tariff and a fixed rate tariff. Thus, it is recommended that at least one price-based or incentive payment-based demand response tariff is introduced alongside the smart metre rollout.

In addition to voluntary-based demand response, there could be a role for direct load control tariffs, which may provide a useful balancing service during peak times as 'negawatts' capacity or for frequency response. This is particularly suitable for residents interested in receiving incentives for participation, but do not want the hassle of actively reducing their energy demands. Such programmes have been widely tested at a state-level in the USA, but the UK has had limited experience with automation. The concept involves utilities remotely turning off or turning down consumers' appliances and equipment during peak times. The specifics are negotiated in a contract beforehand when residents first sign up to the programme. There is much concentration on active demand-side participation (see [52]), which is important, but these discussions fail to acknowledge that not all consumers may want to actively participate due to the potential time and hassle involved, and some may prefer to act passively or not participate at all.

Table 2 summarises the main policy recommendations of the review for the UK.

8. Conclusion

Policy objectives for carbon emissions reduction, energy security and affordability are increasingly moving to the forefront of the political agenda. Historically, there has been a concentration on supply-side solutions, but in the face of current high investment costs for many low(er) carbon power options and the variability of preferred options, such as wind power, energy utilities are exploring complementary ways to meet the growing pressures from governments, stakeholders and the public. Alternative

Table 2
DSM policy recommendations.

Policy recommendation	Regulatory	Market-based	Financial	Voluntary
Utility obligation	For SMEs	–	–	–
Product labelling	Improve accuracy of EPCs & DECs Make mandatory for non-domestic buildings	–	–	–
Product standards	EU regulations	–	–	–
Demand response tariffs	–	Mandate at least one tariff	–	–
Market transformation	–	Policies to remove non-financial barriers	–	–
Funding mechanisms	–	–	[a]Explore funding options	–
Information campaign	–	–	–	Introduce information hub for industry
Marketing campaign	–	–	–	Fund green deal marketing campaign

[a] Funding mechanisms: decoupling, Lost Revenue Adjustment Mechanisms,, shareholder incentives (shared benefits, performance targets, rates of return), revenue regulation, recovery of foregone revenue and DSM programme costs, direct incentives for DSM, System Benefits Charges (see [115]).

solutions include energy storage, cross-border interconnections, and demand-side management (DSM). The paper detailed the results of an extensive two-year review into the literature on DSM policy. The policy aspects of DSM have received less attention than DSM technological trials, modelling studies and theoretical papers, and the research contributed to filling this gap. It proposed a new definition of DSM based on current policy objectives, reviewed global experiences with DSM policy, discussed the UK context and the influence of the EU, and provided policy recommendations for the UK.

Despite recent criticism the UK has had a long and successful history with DSM, particularly energy efficiency policy. Since the mid-1990s the UK has tested various types of policies, such as regulatory (e.g. EESOP1-3, EEC1-2, CERT/CESP, ECO), market-based (e.g. energy efficiency market transformation, Economy 7/10), financial (e.g. Feed-in tariffs, Renewable Heat Incentives, Enhanced Capital Allowances, micro-generation subsidies), and voluntary (Green Deal, information campaigns). The utility obligations have been particularly successful in comparison to other policy types. The EU has also had an important influence on the development of UK DSM policy. Notably, the *Energy Efficiency Directive* (2012/27/EU), the *Smart Meter Rollout Directive (2009/72/EC)*, the *Energy Labelling Framework Directive* (2010/30/EU), and the *Ecodesign Framework Directive* (2005/32/EC), have helped to improve the monitoring and visualisation of energy consumption, and increase the energy efficiency of appliances, equipment and buildings.

However, the UK's current DSM policy appears confused, and the replacement of a utility obligation (CERT) with a voluntary mechanism (the *Green Deal*) has seen the rate of energy efficiency installations plummet. Furthermore, the reduction in residential tariffs to four may negatively affect the potential for the introduction of price-based or incentive payment-based demand response tariffs. There appears to be a political shift from regulatory and financial DSM policies to market-based (Capacity Market participation) and voluntary (industrial information hub) policies. Global experiences have shown that without regulatory and financial support, DSM policies are often less effective.

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